Establishing indigenous vegetation in degraded natural or constructed wetlands*

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Abstract

Increasing the cover and diversity of native wetland plants in constructed or degraded natural wetlands can improve their habitat value, water treatment capability and aesthetic appeal. This article describes a method for successfully establishing indigenous aquatic vegetation within wetlands. (*The Victorian Naturalist* 132 (5) 2015, 147-153)

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Introduction

In Victoria, 50% of the area of natural wetlands has been destroyed since European occupation (DCE 1992). Restoring degraded natural wetlands, or establishing indigenous vegetation in constructed wetlands, provides an opportunity to increase the habitat available for a wide variety of plants and animals that have become rare because of habitat loss. These wetlands also provide places where people can learn about and enjoy natural ecosystems. For example, the 48 hectares of revegetated wetlands and terrestrial areas at the Waterways (Fig. 1), near Edithvale in Melbourne's south-eastern suburbs, have attracted over 100 species of birds, including the rare Magpie Goose, and seven species of frogs. They also support over 220 species of indigenous plants, including 14 rare and threatened species such as the nationally vulnerable Swamp Everlasting *Xerochrysum palustre*. This area is regularly visited by nature lovers and other members of the public.

To provide water quality improvement function in constructed wetlands or restore the biodiversity of degraded natural wetlands, it is necessary to deliberately establish or increase the abundance and diversity of indigenous plant species. The establishment of vegetation within wetlands can present a number of unique challenges. The information and techniques that can be used to overcome these challenges presented here have been developed through 15 years of practical experience in growing and successfully establishing wetland vegetation. Clewell *et al.* (2005) provide more detailed guidelines for developing and managing ecological restoration projects.

Methods

The methodology for establishing wetland vegetation involves the following steps:

1. Determine the physical, chemical and biological characteristics of the wetland environment to be revegetated
2. Determine the function (habitat, water treatment etc.) and characteristics (height, density, appearance etc.) of the vegetation to be established
3. Set goals for plant establishment
4. Select appropriate species
5. Source plant material
6. Plant and establish desired species
7. Maintenance
8. Monitoring

Critical aspects of each of these points will be discussed in detail for both natural degraded and constructed wetlands. It should be noted that to improve the health and diversity of vegetation in natural degraded wetlands it is first necessary to address or manage degrading processes such as grazing, cropping, altered hydrological regimes or artificially high nutrient inputs. Indeed, this may lead to plant re-establishment without the need for further intervention.

1. Determine the physical, chemical and biological characteristics of the wetland environment to be revegetated

The composition, structure and distribution of vegetation that will grow in a wetland are de-

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Fig. 1. Revegetated habitat wetland at the Waterways. Dominant species include Running Marsh-flower *Villarsia reniformis* and Fine Twig-sedge *Baumea arthrophylla*.

termined by a combination of physical, chemical and biological factors. An understanding of these factors and how they influence vegetation is essential when determining what plants to establish and where to put them.

Inundation depth, duration, frequency and seasonality have a major influence on what species grow where within wetlands. When planning wetland revegetation, it is helpful to map out areas in terms of their hydrological habitat, which requires topographic information combined with data on known or modelled wetting and drying cycles. A schematic cross-section of these zones and the plants which grow in them is a useful tool. A combination of the following generalised habitats may be found around most wetlands and usually support distinct associations of plant species.

i) The interface zone between the wetland and surrounding terrestrial vegetation: is above the normal high water level but soil moisture is influenced by lateral seepage and may be saturated during winter and inundated for short periods after rain events. The plant species occurring in this ecotonal environment vary from sedges, rushes, grasses and other herbaceous plants to shrubby thickets of Tea-tree (*Melaleuca* and *Leptospermum* species) in higher rainfall areas or Lignum *Duma florulenta* in low rainfall areas.

ii) Meadow zone: often has a very shallow gradient and is inundated by up to 100 mm at normal high water level and dries out seasonally. Drying out assists in the nutrient cycling process. Common life forms of this habitat include erect emergent sedges (*Eleocharis, Carex, Cyperus* and *Baumea* species), rushes (*Juncus* species), grasses (*Poa* and *Amphibromus* species) and tufted or spreading herbs (*Lobelia, Goodenia* and *Eryngium* species).

iii) Shallow Marsh zone: is inundated from 100 mm up to 250 mm at normal high water level and usually drying out completely during summer and autumn or drought. Common lifeforms include erect emergent sedges (*Eleocharis, Carex, Cyperus, Bolboschoenus* and *Baumea* species), rushes (*Juncus* species), grasses (*Glyceria* and *Amphibromus* species) and amphibious herbs with floating or emergent leaves (*Myriophyllum, Triglochin, Orn-*

duffia, Marsilea, Ranunculus and floating-leaved *Potamogeton* species).

iv) Deep Marsh zone: is inundated from 250 mm up to 1000 mm at normal high water level, the Deep Marsh zone is generally permanently inundated but may dry out completely during drought. Common lifeforms include tall erect emergent sedges (*Eleocharis sphacelata, Baumea articulata* and *Schoenoplectus tabernaemontani*) and aquatic herbs with floating, emergent or submerged leaves (*Myriophyllum, Triglochin, Ornduffia, Nymphoides* and *Potamogeton* species) and free floating species such as *Azolla* or duckweeds.

v) Open Water zone: is greater than 1000 mm deep and generally supports no emergent vegetation. This zone may support submerged aquatic plants such as Eel Grass *Vallisneria americana* and Pondweeds *Potamogeton* species.

Wetting and drying cycles are critical for maintaining the health of wetland vegetation (Butcher 2008). Reduction in water level or complete drying out due to evaporative loss over dry seasons, termed draw down, is important in the cycle of nutrient breakdown and release. It maintains macrophyte species composition and structure and promotes the flowering, seed production and recruitment of many species of plants. It also provides the mud flat habitat preferred by many species of wetland birds such as Dotterels, Plovers and Sandpipers.

Wetlands that maintain high water levels year round due to artificial inputs of stormwater or irrigation run-off often become dominated by vigorous, warm-season growing plants such as *Typha, Phragmites* and *Schoenoplectus* species, which can outcompete many other species and reduce biodiversity (Roberts and Marston 2011). In natural degraded wetlands the act of restoring natural wetting and drying cycles may be enough to stimulate the re-establishment of many plant species.

Constructed wetlands should be designed so that they provide meadow, shallow marsh and deep marsh habitats with appropriate wetting and drying cycles. There are many examples of constructed wetlands where plant establishment has failed or been poor because imposed hydrological regimes are just too different from natural cycles. This problem can be overcome by innovative design informed by an understanding of wetland ecology.

For example, constructed wetlands can be designed to have distinct ponds or cells separated by overflow weirs. One pond is the primary treatment cell through which all incoming water passes. During times of normal low flow, this is the only cell through which water moves. Water flows into other cells only on occasions after rainfall events in which water levels in the primary cell rise high enough to overtop their overflow weirs. In this way, close to natural wetting and drying cycles can be achieved in these normally still water ponds, and diverse vegetation can be established within them. The primary treatment pond may experience a fairly artificial water regime, with near constant flows, and therefore supports only fairly simple riparian vegetation.

Constructed wetland inlets and outlets should be designed so that floodwaters entering wetlands are retained only for a short time in order to prevent plants from drowning or becoming covered in algae. In areas with large catchments it may be useful to have a bypass channel which allows high flows around the wetland to prevent regular pulsing of water levels during the plant establishment phase. An ability to raise and lower levels by the use of weirs and sealable outlet pipes can be useful for plant establishment and management purposes such as weed control or facilitating summer draw down.

Salinity, pH, turbidity and substrate characteristics

The physical and chemical characteristics of water and soils within wetlands are also important in determining what will grow in a wetland (Roberts and Marston 2011). While some plant species seem to thrive under a wide range of environmental conditions, many others do well only within a particular range of salinity, pH and turbidity. It is important to note that some of these characteristics may vary widely within a wetland depending on seasonal changes; for example, a wetland may be quite fresh during wet periods but become quite saline in dry times.

Soil nutrient levels and water holding capacities also play a major role in determining plant species composition within wetlands. Wetlands occurring on heavy clay soils will support flora very distinct from those occurring in sandy areas, even if their hydrological regimes are similar. Plant establishment within constructed wetlands is greatly enhanced if at least 150 mm of local topsoil is spread in areas in which aquatic plants are desired.

Wave action
Wide, open bodies of water with a large surface area can be subject to intense wave action caused by strong winds. This wave action can cause bank erosion and prevent the establishment of many plant species. Such water bodies, unless they have very gentle bank gradients (i.e. of a higher ratio than 1:30), will usually support only simple vegetation communities. Wave action can be reduced in constructed wetlands by decreasing the length (fetch) of a water body in the direction of prevailing winds, using islands or shallowly submerged bunds.

2. Determining the function and characteristics of the vegetation to be established
The primary functions of a constructed wetland will determine what kinds of plant species and associations will be desirable to establish within it. Wetlands with the primary function of water treatment will need large areas of dense emergent macrophytes that will intercept water flow, facilitate deposition of suspended sediments, and support a large surface area of biofilm (consisting of fungi, algae and bacteria). The emergent macrophytes which are best suited to this role are those that grow rapidly, take up substantial quantities of nitrogen and phosphorus, and do not die off in cool seasons, for example *Baumea articulata* and *Eleocharis sphacelata*. They will also require deep areas with no emergent vegetation to allow maximum sunlight penetration so that ultraviolet radiation can kill undesirable bacteria.

Constructed wetlands with the primary function of wildlife habitat should be planted with the plant species whose characteristics provide for the habitat requirements of the wildlife species for which they are being designed. For example, dense stands of Water Ribbons *Triglochin procerum* and submerged beds of Eel Grass and Pondweeds are the favoured habitats of the Growling Grass Frog *Litoria raniformis* and Green and Gold Grass Frog *Litoria aurea*, as they provide ideal surfaces on which to bask and dense cover in which to hide from predators. Wetlands with the primary role of increasing aesthetic values should be planted with attractive species that produce massed displays of flowers, such as *Ornduffia* or *Nymphoides* species, or have interesting foliage colour and texture, such as *Myriophyllum* and *Triglochin* species. The use of tall, vigorous emergent sedges in such areas is to be avoided as they will ultimately obscure views into the wetland. Well-designed or managed wetlands can perform all of the above functions as long as areas with conflicting requirements are kept separate. Visiting intact remnant wetlands is the best way to see how this can be achieved.

Retain, enhance and interpret existing ecological, landscape and cultural features, such as large old trees, remnants of native vegetation and sites of archaeological or historic significance. These are valuable assets that will be of interest to the local community and help to create a unique sense of place.

3. Setting goals for plant establishment
How densely a wetland is planted will determine how rapidly aquatic vegetation is established, and the cost of planting and weed maintenance. The Interface, Meadow and Shallow Marsh zones are those most susceptible to weed invasion in the early phase of wetland vegetation establishment. Experience has shown that, if competent weed control is carried out, a density of 5–6 plants per square metre is adequate for these zones. Under good conditions this should result in 90% cover of desirable species within nine months of planting.

The Deep Marsh zone can be planted at four plants per square metre, and will take slightly longer to fill out (Fig. 2). Planting at a high density will allow desirable plants to quickly form an interlocking canopy that will help prevent erosion and weed invasion. The money saved from buying a smaller number of plants, and planting them sparsely, will soon be consumed by the cost of controlling weeds.

4. Species selection
When selecting which species to establish in a wetland, it is important to consider any information available on the physical, chemical and biological characteristics of the wetland environment. As mentioned above, factors such as wetland shape, soil types, salinity and pH will

Fig. 2. Restored near-coastal wetland at Torquay. This deep marsh area, planted at a density of four plants per square metre with Water Ribbon *Triglochin procerum* and Tall Spike-rush *Eleocharis sphacelata* has a good cover of aquatic species after 12 months of growth.

all influence which species will be most appropriate. Nearby intact remnant wetlands, with similar environmental characteristics to the area to be planted, are probably the most useful reference in determining what species to use for revegetation.

When selecting species, use some coloniser plants and begin a process of natural succession. Many wetland plants including species such as *Crassula helmsii, Elatine gratioloides, Lythrum hyssopifolium, Juncus bufonius* and *Isolepis*, other *Juncus* and *Epilobium* species fill the ecological niche of colonisers, and rapidly colonise bare areas that may otherwise be invaded by undesirable weeds. By purposefully planting a small proportion of coloniser species, it is possible to increase the speed at which desirable species reach a high cover and to put in place a soil seed bank which will protect the wetland in the event of any future disturbances.

5. Sourcing plant material

Using local genetic stock ensures that plants are well adapted to local soil and climatic conditions. It also decreases the likelihood of confusion between species or subspecies for which the current taxonomy is unclear.

Aquatic and semi-aquatic plants can be grown in a range of formats. The format selected for each species should be determined by its growth form, size, habitat preferences and ecology. Large rhizomatous sedge species, including *Baumea articulata* and *Eleocharis sphacelata*, establish best if planted from containers, such as 3 or even 6 inch pots, which allow the development of thick rhizomes and tall stems (over 1 metre in size). These characteristics maximise the success of establishment under conditions of high turbidity, wave action, avifaunal grazing and rapid water level fluctuations which can cause high plant mortality rates, particularly for plants planted in the shallow and deep marsh zones. Spreading herbaceous plants such as *Crassula helmsii* and *Myriophyllum* species are best grown in broad, shallow containers. Tussock-forming sedges and grasses, such as *Carex appressa* and *Poa labillardieri*, are best grown as tubestock or planting cells larger than 16 cm^3. Using small-sized planting cells, less than 16 cm^3, usually results in high plant mortality.

6. Planting and initial establishment

The timing of planting of aquatic and semi-aquatic species is crucial if successful establishment is to be maximised. The optimal time for planting is just before a species enters its optimal growing season. The growing season of wetland plants varies. Plants which grow on the fringe of wetlands often grow best in cool, moist conditions when there is plenty of moisture available in this zone, while true aquatics often grow most rapidly when the weather is warm.

Species which occur in deep water habitats are best planted when water levels are lowest in natural wetlands or before the normal high water level is reached in constructed wetlands. Once over the initial shock of planting, and if they are planted in their preferred growing season, these species are often quite capable of growing to keep up with a slow but steady increase in water level. Large rhizomatous sedge species such as *Baumea articulata* and *Eleocharis sphacelata*, should be planted at the shallow edge of their preferred habitat—i.e. in 200–300 mm of water—rather than out in deeper water, which is a hostile environment for establishing young plants. Once well-established in the shallows, these plants will grow out into deeper water.

Plant Protection

A common cause of failure of establishment of some wetland species is that they are destroyed by grazing waterbirds while still small and vulnerable. If plants can be protected through the first growing season even the most palatable species can become established enough to survive the destructive feeding habits of birds such as Purple Swamp Hens or Black Swans. Protection of young plants is particularly crucial in degraded natural wetlands or constructed wetlands close to areas where there are established populations of wetland birds.

Protection is best achieved by suspending an enclosure made of netting or small gauge bird wire around young plants. This material should be arranged so that plants will have space to grow for a full growing season without becoming entangled within it, otherwise it becomes difficult to remove and re-use. Great care must be taken to ensure netting or wire is taut and that there are no points of entry into enclosed areas or wildlife may become entangled or trapped and drown.

Fig. 3. Given optimal conditions, including natural wetting and drying and protection from waterbird grazing, wetland vegetation can establish very rapidly. This sequence of photographs, taken over a nine month period, shows vegetation establishment in a constructed wetland from newly constructed and bare of native species on the above left to well vegetated with a high cover of indigenous plants and minimal weeds on the lower left.

7. Maintenance

In order to establish aquatic vegetation in wetlands, it is crucial to eradicate and suppress the establishment of certain key weeds by means of a well budgeted, designed and implemented weed control strategy, which includes timely application of appropriate methods, monitoring and follow up. High threat wetland weeds in Victoria are ranked in DSE (2008). Ideally weed control should be carried out by specialist contractors or skilled volunteers with proven ability to identify indigenous and weed species. If performed correctly, weed control will encourage regeneration of indigenous species and result in successful vegetation establishment.

8. Monitoring

Regular inspections of establishing wetland vegetation should be made over the first 12 months to monitor its progress and assess if adaptive management is required. The frequency of these inspections should be between every two to four weeks, and additional visits should be triggered by large rainfall events that may cause flooding. The checklist of things to be monitored during each inspection include photo points (Fig. 3) plant health, weed invasion, the effects of rainfall and evaporation on water levels, any impacts from wave action, water salinity, turbidity and pH, impacts from pedestrian traffic or dog walking, wetland bird grazing and fauna colonisation.

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Bird vomit, the tour leader and the butcherbird 'sweet tooth'

While visiting Uluru last year, Fred Bohner, Kathy Himbeck and I decided to do the Mutitjulu Waterhole walk. While we were taking our time birdwatching and enjoying the scenery of this sacred place, a pair of Pied Butcherbirds *Cracticus nigrogularis* were seen regularly taking food back to their nest. After observing these birds for a few minutes we walked further and caught up to a tour group from a well-known Australian/New Zealand bus tour company. Not wanting to walk through the group, as their tour leader was talking with them, we stood back and listened to her spiel. Our interest in what she was saying was heightened when she started referring to a white coating all over the leaves of some small saplings as 'bird vomit'. On a closer inspection, after the group had moved on, the 'vomit' was found to be the lerp casings of the nymph stages of psyllid insects. It was a heavy infestation on the sapling gums, as can be seen in Fig. 1.

Being a stickler for correcting misinformation, especially about natural history, I spoke to the guide quietly and let her know that the 'vomit' was in fact the sugary secretions of sap-sucking insects. She was going to check with her source of information, a local *Anangu* young man, who was a fellow tour leader. Whether the bird vomit relates to a traditional story, I have been unable to determine.

On our return walk from the waterhole, I observed an immature butcherbird on the ground, picking up items from the soil and eating them. As the bird was distracted by what it was doing, I was able to get close enough to take a series of photos. After the bird flew off, I walked over to